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O. Baturin, G. Levagin, O. Kolomiycev, E. Ryabokon

Ivan Kozhedub Kharkiv National Air Force University, Kharkiv

THE STATISTICAL CHARACTERISTICS OF AXIAL-SYMMETRIC ANTENNAS

The article contains the expediency of using the method of statistical tests for calculation of axisymmetric antennas statistical characteristics. The analysis of average performance of circular antenna arrays is carried out.

Keywords: *antennas, circular antenna arrays, directional diagram, amplitude phase distribution.*

Modern aircraft characteristics impose high requirements rate of updating of the environment information, what stipulates transition to active antenna arrays (AAs) and new methods of area survey, used in survey systems.

In majority of modern radar with electronic scanning, the plane antenna arrays are used, which have a number of disadvantages at omnidirectional scanning, and so plane antenna arrays are proposed to be replaced with axisymmetric ones, in particular, circular antenna arrays (CAAs). Such arrays are preferred for realization of such survey methods as parallel survey or ultra high-speed scanning.

The question arises as for level of technical requirements to manufacturing precision and operating conditions of antennas systems with CAA.

The founder of the statistical antenna theory is Y.S. Shifrin. The problems as for linear AAs [1–5] are widely covered in his works and works of his disciples. General approach of this theory applied for CAA is studied not enough.

Antenna arrays with the great value of ratio L/λ and complicated multichannel feed system are usually used in such systems. As a result, the role of factors generating the random spread of antenna parameters, considerably increases, what causes the necessity of study of their statistical characteristics.

Various statistical methods are used to study real antenna characteristics. The method of characteristic functions most fully developed and mostly used one. It is rather universal and suitable at analytical study when the errors are multiplicative. It is reasonable to use a spectral representations method when the errors are additive. If a source of errors is some specific mechanism (for example, inaccuracy of mounting of feed element in a reflector antenna) or the characteristic of radiation problem (RP) to be found is expressed by the functional equations (which are unsolvable in general form), the canonical decomposition method or asymptotic approximation method are used.

When using the method of characteristic functions for the analysis of complicated antenna types (e.g., convex, antenna), the obtained expressions are intricate and this makes difficult their correct physical interpretation. Therefore, for such antennas in the presence of initial formulae, describe of the antenna field with errors, it is reasonable to use the statistical test method by entering data about the amplitude phase distribution (APD) errors or antenna design parameters by means of random-number generators with desired distribution laws.

An arisen instability can cause the errors (amplitude, phase and frequency ones) both in whole antenna system and in its elements. Thus, the errors can have different correlation radii what should be taken into account when analyzing the system.

The phase errors exert essential influence on the characteristics of antenna systems.

Considering main questions of statistics of the CAA field with random phase errors, mean antenna characteristics such as mean RP, mean directive gain (DG), dispersion of principal maximum direction drift as well as some fluctuation characteristics, particularly the errors of angular coordinates measurement were analyzed.

The following initial formulae for undistorted RP were used:

– at parallel survey:

$$f_0(\varphi) = \sum_{n=-N}^{N} a_n \cdot e^{j\cdot k\cdot r\cdot \cos(n\cdot\delta\alpha-\varphi)} \times \\ \times e^{-j\cdot k\cdot r\cdot\cos(n\cdot\delta\alpha-\varphi 0)} \times \cos(n\cdot\delta\alpha-\varphi)\times \\ \times\cos(n\cdot\delta\alpha-\varphi_0), \quad (1)$$

where $\cos(n\cdot\delta\alpha-\varphi_0)$ is the RP drift with respect to the center of the 0,7 power PR, the expression under the sign of sum is determined as follows:

– for MQS:

$$f_0(\varphi) = \sum_{n=-N}^{N} a_n \cdot e^{j\cdot n\cdot(\varphi+\Omega\cdot t)}; \quad (2)$$

– for real RP:

$$f(\varphi) = \sum_{n=-N}^{N} a_n \cdot e^{j\cdot\sigma\cdot\Delta\varphi_n} \times \\ \times e^{j\cdot k\cdot r\cdot\cos(n\cdot\delta\alpha-\varphi)} \cdot e^{-j\cdot k\cdot r\cdot\cos(n\cdot\delta\alpha)} \times \\ \times\cos(n\cdot\delta\alpha-\varphi)\cdot\cos(n\cdot\delta\alpha); \quad (3)$$

$$f(\varphi) = \sum_{n=N}^{N} a_n \cdot e^{j \cdot n \cdot (\varphi + \Omega \cdot t + \Delta\varphi_n)}, \qquad (4)$$

where $\Delta\varphi_n$ is the random phase error in the n-th CAA element.

The analysis of mean RP makes possible to determine the influence of error on the RP form, reduction the power magnitude radiated in the main maximum direction decreases and mean RP change what errors correlation radius varying as follows:

$$\overline{|f(\varphi)|}^2 = (1-\sigma^2)|f_0(\varphi)|^2 + \sigma^2 I(\varphi) . \qquad (5)$$

When $\overline{\Delta\varphi_n^2 << 1}$, the mean power RP represents the sum of undistorted RP with coefficient k~$(1\text{-}\sigma^2)$ and scattered power pattern $I(\varphi)$ at different relative correlation radii C given in fig. 1.

As can be seen, at small correlation radii C, the scattering pattern $I(\varphi)$ is insignificant and "directional characteristics" of this function are poorly expressed, i.e. $I(\varphi)$ represents almost constant "background" of side lobes. The magnitude of this background at the specified value of error dispersion is determined by the relation of the error correlation radius to the length of system. When increasing the correlation radius the magnitude and "directivity" of $I(\varphi)$ the function increase.

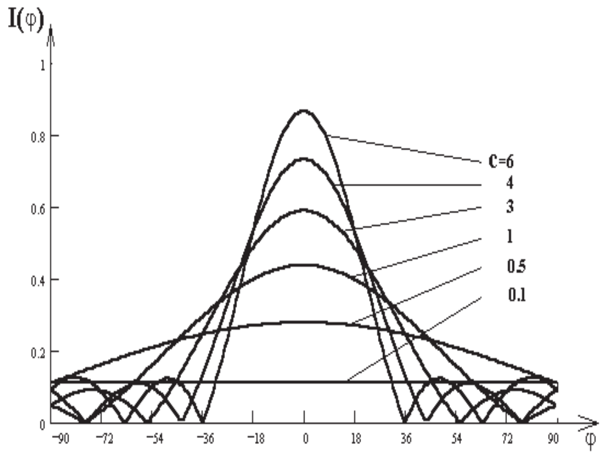

Fig. 1. Scattering pattern $I(\varphi)$ at different values of errors correlation radius

In order to find out the "mechanism" of reduction of the antenna mean DG, it is expedient to take into account the character of the main lobe width versus the error correlation radius. In this case, the system mean DG dependency on the error correlation radius has a view presented in fig. 2.

This figure shows that a magnitude of the mean DG relative reduction decreases as a correlation radius increases. Thus, DG reduction is equal to that of power which is being radiated to the main maximum direction.

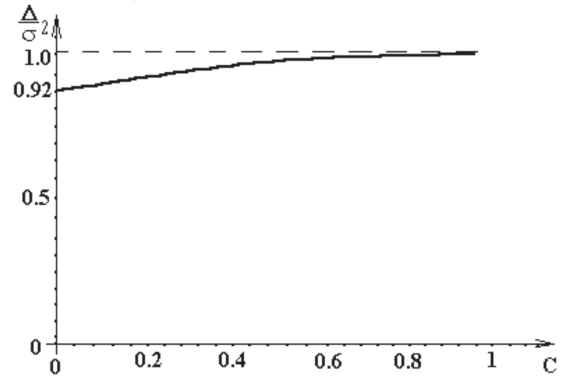

Fig. 2. Reduction of the mean DG at different correlation radii

At uncorrelated errors, the magnitude of Δ depends on an amount of radiators and error dispersion. At correlated errors, the mean DG reduction depends on the correlation radius as well. The obtained dependencies of the DG reduction in the presence of errors can be explained by two effects, namely: the main lobe broadening and side lobe level increasing. DG reduction caused by the first effect is insignificant in the considered case. So, the increase of the mean side lobe level mainly contributes in DG reduction.

The most essential effect at phase distribution distortion along the antenna is the main maximum directions drift. This effect is one of the most unpleasant results of the phase error presence, further leading to errors of the angular coordinate measurement. Therefore, analysis then of the antenna the fluctuation parameters is the next step of the antenna field statistical analysis after consideration of antenna mean characteristics. The results of estimation are presented in fig. 3.

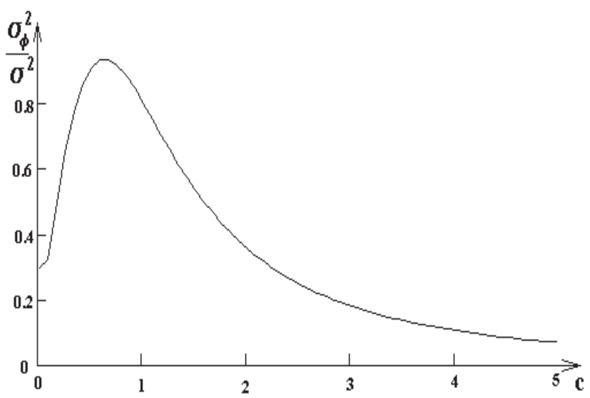

Fig. 3. The dependency of the main maximum direction dispersion from the correlation radius

The research of the influence of error correlation radius on the main maximum direction drift has revealed as expected that error dispersion tends to zero when correlation radius tends to zero or to infinity.

A physical meaner of this sense is explained in the following way: at very small radius the number (N) of harmonics, in which DG is decomposed, is great enough. It is on symmetry reasons that the direction of field maximum $\Delta\varphi$ is highly close to the direction $\varphi = 0$ in this case. The system is practically in-phase at very large radii, and for the in-phase systems $\Delta\varphi = 0$. The maximal main maximum drift dispersion is to be observed when the aperture is comparable to the correlation radius.

The research of the influence of phase shifters discreteness on the direction finding sensitivity (DFS) was carried out as well. The obtained results had been compared with the DFS of flat AA and with that DFS of CAA of the same size.

The obtained results show that when using the phaseshifters with great discreteness (of DFS: 0°-22,5°) DFS in CAA is worse than in the equidistant AA. This discrepancy is smoothed when phase shifters with smaller discreteness (of DFS: 0°-11,25°) are used.

Thus, it is possible to conclude that there are two basic mechanisms of error formation in circular antenna arrays depending on used survey mode.

1) At the parallel survey, the resulting error consists of errors in each channel and a common error in the CAA aperture.

2) At superfast scanning, the resulting error consists of pattern-forming unit' errors and the terminal antenna waveguide channel ones.

The feature connected with application of the statistical theory to the CAA, is substitution of generalized angle "ψ", which is used for the linear antenna arrays for the real one "φ".

The statistical analysis results allow asserting:

1) errors the following different mechanisms differently influence on the statistical characteristics of circular antenna arrays;

2) the character of these dependencies differs somewhat from the similar dependencies for linear antenna arrays;

3) these distinctions are comparatively insignificant at small errors and at the large antennas radius to wave length ratio.

Thus, the errors in CAA elements affect on its statistical characteristics in the same way as in the linear antennas, so requirements to a manufacturing accuracy and elements stability are the same as for linear antennas.

Application of the statistical test method enables to simplify estimation of the complex type antenna statistical characteristics and their analysis to the maximum degree.

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Рецензент: д-р техн. наук ст. наук. співробітник Г.С. Залевський, Харківський національний університет Повітряних Сил імені Івана Кожедуба, Харків.

СТАТИСТИЧНІ ХАРАКТЕРИСТИКИ ВІСЕСИМЕТРИЧНИХ АНТЕН

О.В. Батурін, Г.А. Левагін, О.В. Коломійцев, Е.О. Рябоконь

В статті розглянуто доцільність застосування під час розрахунків статистичних характеристик вісесиметричних антен метода статистичних випробувань. Проведено аналіз середніх характеристик кільцевої антенної решітки.

Ключові слова: *антена, кільцева антенна решітка, диграма спрямованості, амплітудно-фазове розподілення.*

СТАТИСТИЧЕСКИЕ ХАРАКТЕРИСТИКИ ОСЕСИММЕТРИЧНЫХ АНТЕНН

О.В. Батурин, Г.А. Левагин, А.В. Коломийцев, Е.А. Рябоконь

В статье рассмотрена целесообразность применения при расчетах статистических характеристик осесимметричных антенн метода статистических испытаний. Проведен анализ средних характеристик кольцевой антенной решетки.

Ключевые слова: *антенна, кольцевая антенная решетка, диаграмма направленности, амплитудно-фазовое распределение.*